THE EFFECT ON ANGULAR DISTORTION OF WELDING CURRENT ON AUSTENITIC STAINLESS STEEL FLANGED PIPE WITH TIG METHOD WELDING

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Abstract

Stainless steel flanged pipe formed by the welding are used commonly in nuclear, chemical, petroleum and food industries in which the corrosion resistance has importance. In the stainless steels, the distortions are occurred at an important rate due to excess heat input in welding method. This situation causes time, labor force and repair costs.

In this study, angular distortion values - the most effective distortion - observed in welded flanged pipes was investigated. Austenitic stainless steel flanged pipes were produced by tungsten inert gas (TIG) method with or without filler rod. The most important parameter affecting the temperature rise in heat affected zone (HAZ) is the welding current. Therefore, experimental study was carried out by using welding current (70, 80, 90, 100 and 110 A) deemed worthy of researching.

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TIG METOT KAYNAĞI İLE ÖSTENİTİK PASLANMAZ ÇELİK FLANŞLI BORUDA KAYNAK AKIMININ AÇISAL DİSTORSİYONA ETKİSİ

Özetçe

Kaynaklı imalat yöntemiyle şekilendirilmiş paslanmaz çelik flanşlı borular özellikle korozyon direncinin öncelikli önem arz ettiği nükleer, kimyasal, petrol ve gıda sektörlerinde yaygın olarak kullanılmaktadır. Kaynak yöntemiyle birleştirmelerde bölgesel ısı oluşumu nedeniyle özellikle paslanmaz çeliklerin kaynağı sonrası önemli miktarda distorsiyonlar oluşmaktadır. Bu durum, zaman ve işgüücü düzeltme maliyetlerine neden olmaktadır.

Bu çalışmada, kaynaklı imalat boru-flanş birlştirmelerde distorsiyon çeşitlerinden en etkilisi olan açısal distorsiyon değerleri araştırılmıştır. Araştırmada, 2 mm sac kalınlıdığında ostenitik paslanmaz çelikten (AISI 304) boru-flanş birleştirmelerinde dolgu telsiz ve dolgu telli manuel TIG metot kaynak yöntemleri kullanılmıştır. Birleştirme bölgesinddeki ısı artışını etkileyen en önemli parameter kaynak akımıdır. Bu nedenle, deneysel çalışmalar 2 mm sac kalınlığı için araştırmaya değer görülen 70 A, 80 A, 90 A, 100 A, 110 A kaynaak akımı değerleriyle gerçekleştirilmiştir.

Key words: *Angular distortion, TIG (Tungsten Inert Gas), pipe-flange welding, austenitic stainless steel*
Anahtar kelimeler: *Açısal distorsiyon, TIG, boru flanş kaynağı, ostenitik, paslanmaz çelik*

INTRODUCTION

Stainless steels flanged-pipe formed by the welding are used commonly in nuclear, chemical, petroleum and food industries in which the corrosion resistance has importance. In austenitic stainless steels, thermal expansion is high and heat conduction is low [1,2]. Therefore, low heat input must be applied in the welding of austenitic stainless steels. TIG method with low heat input is preferred especially for thin parts [3]. TIG method gives less distortion values with respect to metal inert gas (MIG) method [4].

Welded joints are carried out with local heating. Therefore, the temperature distribution is not uniform in welded part [2,5,6]. This affects

the characteristics of the material, residual stresses, the size and the shape of welded parts. As a result, damages occur in them. In welded flanged-pipe joint fabrication applications, the labor and time cost in correcting angular distortion, as a result of residual stresses engendered by cooling after local heating, is an important trouble [7-9]. Coefficients of thermal expansion of austenitic stainless steel are more than 50%, considering alloy or low-alloy steels [7]. Due to this reason, the angular distortions in the austenitic stainless steel welded joints increases and correction processes increase the labor and time costs in according to structural steels.

Angular distortions are influenced by three main variables - thermal stresses, construction rigidity and metallurgical properties of the material [10]. The increase in value of the welding current increases the local heat input values in welded connections. Therefore, the determination of the most appropriate welding current in welded flanged-pipe connections of austenitic stainless steels is a significant variable to be examined for the minimum cost of fabrication due to minimum angular distortion.

In Austenitic stainless steel welded flanged-pipe connection applications with the manual TIG method, welding employees often prefer welding with high current. The reason for this is that the arc ignites very easily and the welding speed increases proportional to the welding current. Welding faster in order to finish the job more quickly usually gives to work piece more heat input than enough.

Nonetheless, in the applications that the gap between the inner diameter of the flange-pipe and the outer diameter of the pipe is more than enough, TIG welding with filler rod is preferred. In such cases, owing to applying heat more than enough, distortions increase and costs increase in order to resolve problems that arise. Alternatively, instead of continuous welding, distortions can be reduced with a method welding [11].

In this study, we investigated the effect of welding current that was active on local heat input to angular distortions that occur in connections of welded flanged-pipe connection with TIG welding. And also in order to

examine the design of flange and carelessness in its manufacturing, the effect of conditions were examined with or without filler rod to angular distortion.

Experimental studies realized with 70 A - 80 A - 90 A - 100 A and 110 A welding current values for each of with or without filler rod in TIG welding method. Approximate constant penetration width is used in order to assess the changes in welding rates. Experimental results show that the filler rod applications cause the increase in angular distortion values, and the most appropriate angular distortion is obtained at the filler rod conditions that use the welding current "70 A".

EXPERIMENTAL STUDIES

AISI 304 austenitic stainless steel is used for the experimental studies and its chemical composition is given at Table 1.

Material	C	Mn	Si	Cr	Ni	P	S	Others
AISI 304	0.08	2.0	1	18	10	0,045	0,03	-

Table 1. The chemical composition of AISI 304 austenitic stainless steel

Ø 2 mm ER 308L rod was used as the weld filler rod. Its chemical composition is given at Table 2.

Material	C	Mn	Si	Cr	Ni	P	S	Others
ER 308L	0.03	1.0-2.5	0.30-0.65	19.5-22.0	9.0-11.0	0.03	0.03	0.75 Mo 0.75 Cu

Table 2. The chemical composition of the weld filler rod "ER 308 L"

For the experimental studies, the welded pipe with dimensions of $Ø_{outer}$ 139,7 x 400 x 2 mm, was manufactured from AISI 304 sheet metal with dimensions of 400 x 438,66 x 2 mm. Flanges with dimensions of 240 mm (outer diameter), 141 mm (inner diameter) were manufactured from the

same sheet metal with the laser cutting and they have eight holes with the dimension of 18 mm diameter. The assembly drawing of welded flange-pipe is shown at Figure-1. The welding machine "ESAB Origo™ Arc 150i" made all welded connections.
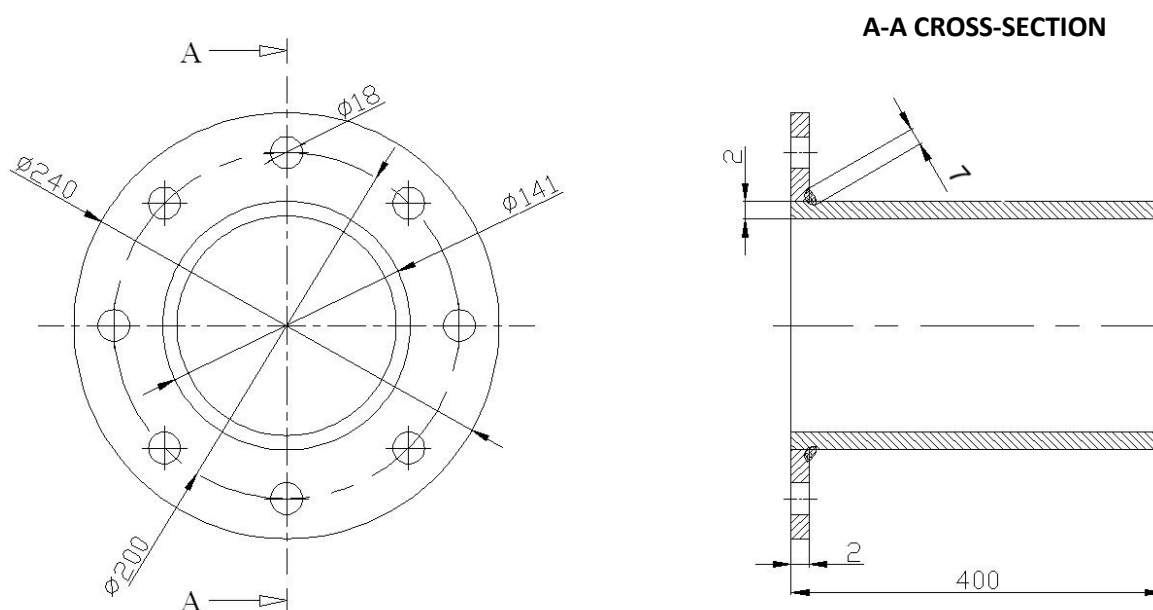

Figure 1. Welded flange-pipe geometry.

In the TIG welded flange-pipe connections, the method welding was preferred, which reduces the amount of heat input to 2/3. Figure 2 presents a diagram of welding plan. According to this plan, flange-pipe was spot welded with mutually 4 points and then welded connection were applied to respectively 1, 2, 3, 4, 5, 6 zones. In order to spread the heat balanced, welding was done reciprocal and in the next step welding was kept going as from the point that heats before. After the welding plan, a template was constituted and the areas to be welded were marked on all the test pieces. In experimental studies, pure argon was selected as protective gas and the flow

rate is 7 lt. / min [12]. In order to study the effect of welding current to angular distortion, the most appropriate welding current value is 45 A / mm, for instance 90 A for 2 mm metal sheet [12]. Therefore, the lower and upper values of 90 A were taken as welding current variable. In this connection, the experimental studies were carried out with 70 A, 80 A, 90 A, 100 A and 110 A current values. Three tests were carried out both with and without filler rod at each welding current and a total of 30-welded flange-pipe studied. The welding details used in connecting processes are shown at Table 3. The penetrating width "6 mm" was selected for the tests with filler rod, and "7 mm" was selected for the tests without filler rod at welded connections. And also the welder fastened the penetrating values by changing the welding speed. After measuring the welding speeds, their changes in processes were evaluated.
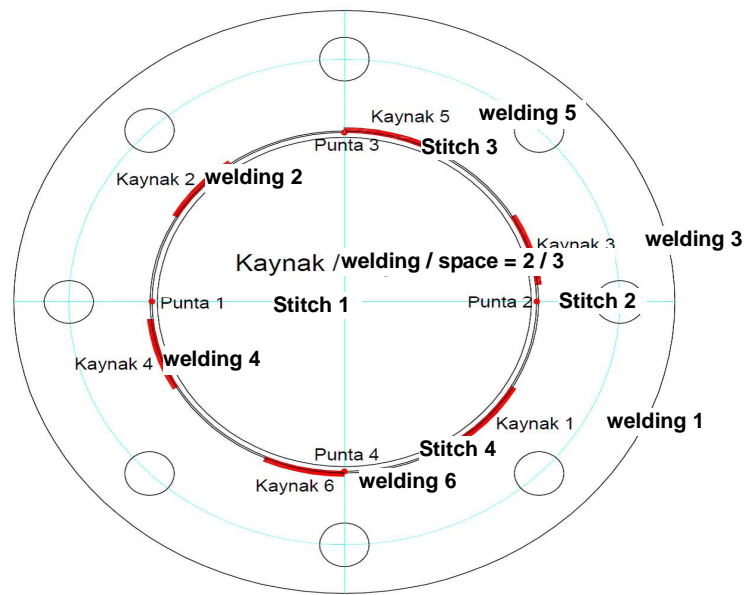

Figure 2. The plan of method-welding

Test No	Current Capacity (A)	Filler Rod	Test No	Current Capacity (A)	Without Filler Rod
Test 1	70	No	Test 16	70	Yes
Test 2	70	No	Test 17	70	Yes
Test 3	70	No	Test 18	70	Yes
Test 4	80	No	Test 19	80	Yes
Test 5	80	No	Test 20	80	Yes
Test 6	80	No	Test 21	80	Yes
Test 7	90	No	Test 22	90	Yes
Test 8	90	No	Test 23	90	Yes
Test 9	90	No	Test 24	90	Yes
Test 10	100	No	Test 25	100	Yes
Test 11	100	No	Test 26	100	Yes
Test 12	100	No	Test 27	100	Yes
Test 13	110	No	Test 28	110	Yes
Test 14	110	No	Test 29	110	Yes
Test 15	110	No	Test 30	110	Yes

Table 3. The welding details used in connecting processes.

To assess the effect of welding current to angular distortion, test sample was attached to lathe chuck from the flange side in a balanced manner. At the same time, it was connected to work bench so that the tailstock can fasten up the test sample from the centre hole. An axis "5 mm" was drawn from outside of flange into it by using the caliper. The dial gauge was put between sixth and first welding zone, and fastened to press to the drawn axis. The pre-press of dial gauge was 5 mm. By turning the lathe chuck by

hand, the deformations in every zone were read from the dial gauge. The picture captured during measuring is shown in Figure 3 and details of the measurement are presented in Figure 4.

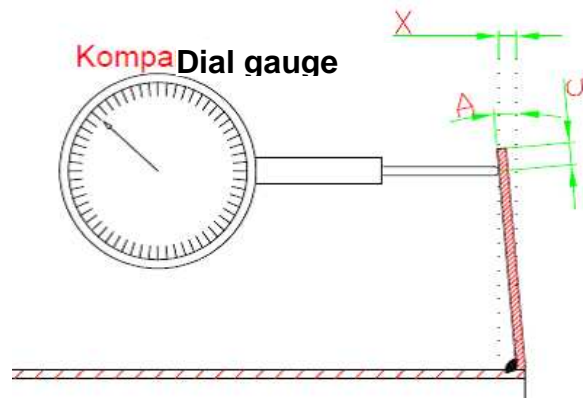Figure 3. The measuring of angular distortion.

Figure 4. The schema of the measuring of angular distortion.

In order to measure the angular distortion, the deviation in the comparator and tangent theorem are used.

RESULTS AND DISCUSSION

The average values of angular distortion and welding speed in tests without filler rod, which measured from the same welding current, is shown in Table 4.

The average values of angular distortion and welding speed in tests with filler rod, which measured from the same welding current, is shown in Table 4.

Welding current [A]	Angular distortion [Degree]	Welding speed [cm/min.]
70	1,54	45
80	1,77	50,2
90	1,93	56,4
100	1,36	62,6
110	0,90	76,4

Table 4. The average values of angular distortion and welding speed in tests without filler rod in TIG welding [13,14].

Welding current [A]	Angular distortion [Degree]	Welding speed [cm/min.]
70	2,19	45
80	2,42	50,2
90	2,67	56,4
100	4,40	62,6
110	3,77	76,4

Table 5. The average values of angular distortion and welding speed in tests with filler rod TIG welding [13,15].

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By using Table 4 and 5, the effects of welding current, angular distortion and welding speed in connections of welded flange-pipe, are presented in Figure 5.
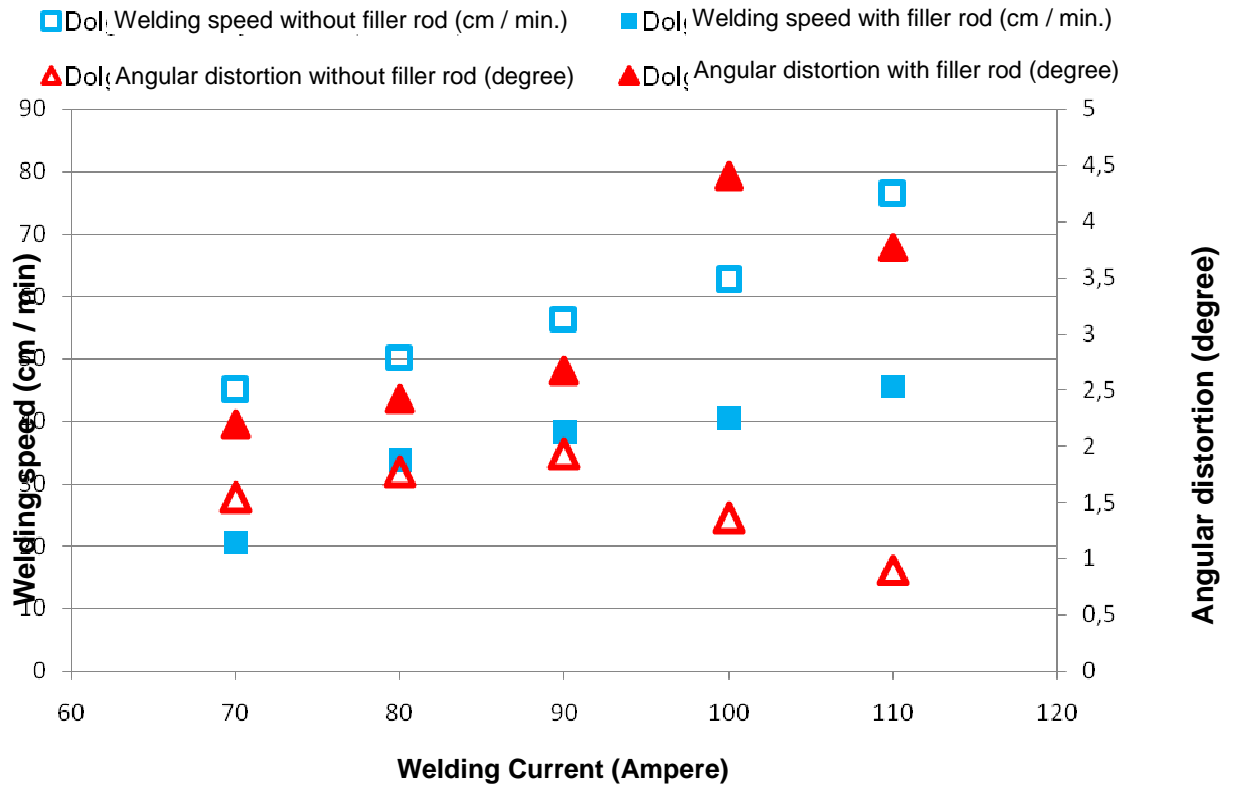

Figure 5. The effects of welding current, angular distortion and welding speed

The increase of welding current value affects heat density of weld zone. As a consequence, weld zone and filler rod -if used- start to melt in a short time together with heat density increase. This situation shows that weld processes occur in a short time. The results of experimental studies reveal that, with the increase in welding current, both with and without filler

rod increases welding speed (Figure 5). When the conditions with and without filler rod compare, Welding has been obtained to take place more quickly in conditions without filler rod beside in all welding current values with filler rod. This result is normal on account of mass decrease to melt, since filler rod is not melted. Table 4, Table 5 and Figure 5 show that, that piece dimensions for applications of TIG welded flange-pipe doesn't necessitate the using of filler rod increase welding speed twice regardless of the values of the welding current. In conclusion, the data obtained from experimental studies show that the increase of welding current increases welding speed and quicker welded connection occur in situations without filler rod.

The relationship between welding current and angular distortion reveals that the welding current values increase linear between 70 and 90 Ampere. This situation occurs both with and without filler rod identically. However, the angular distortion of filler rod occur 37-42 % more. In a research made for 304-type stainless steel (2 mm) at 60-120 Ampere, it showed that the increase of welding current increased the welding seam width [16]. Increase in the welding seam means increase in the amount of the heat-affected zone (HAZ). So that is the bigger deformation as a result of cooling down. And consequently increase at values of residual stress and distortion occurs. Experimental results from 70 to 90 Ampere are consistent with the study of the literature.

The distortion data belong to experimental study in 100 and 110 Ampere welding current conditions showed a different change from linear change at 70-90 Ampere welding current data. While the distortion-decrease without filler rod occurred, % 50 increase in the same conditions with filler rod occurred. This unexpected situation was tried to interpret by examining the flange- distortion shape.

Angular distortion values at the welding currents more than 90 Ampere, which occurs at condition with filler rod, may be expected to increase. However, due to method welding, distortion at its HAZ between two seams must be decreased on account of heat density increase.

Therefore, distortion type up to 90 ampere welding current was high amplitude-low frequency and distortion type at values more than 90 amperes was low amplitude-high frequency. Similar distortion distribution types occurred at conditions without filler rod also. Small angular distortion at conditions over 90 amperes without filler rod can be understood as conditions giving values that is relevant to purpose of the study. However, distortion type at low amplitude-high frequency is a result that is harder to be corrected and takes time. When it is taken into account parameters such as energy, processing time and correction time beside welded connection costs, correction operations cause too much cost increase. Therefore, the least correction, so low angular distortion and high amplitude-low frequency are the most appropriate conditions. The data that provides the most appropriate values are high amplitude-low frequency, welding without filler rod and 70 ampere.

CONCLUSION

The experimental results at TIG welded flange-pipe connections with 2 mm wall thickness of AISI 304 austenitic stainless steel are given as follows:
1.   The welding current values within the range 70-90 were appropriate working values.
2.   Smaller angular distortions occurred at the conditions with filler rod.
3.   70-ampere was the most appropriate value both for welding with and without filler rod.
4.   The least angular distortion was obtained at 70-ampere without filler rod.

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